Ionizing radiation: Alpha, beta, gamma, what?
345
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Solutient Technologies
Thursday, April 1, 2010 2:15 to 3:15 p.m.

Summary
Talk About 1 - Radiation Fundamentals
About 2 – Characteristics of Radiation

Definitions
1. Radioactivity
2. Ionizing radiation
3. Non-Ionizing radiation
4. Radiation Terminology
5. Dose
6. Dose Rate

Radioactivity
Radioactivity is unstable (or radioactive) atoms trying to become stable by emitting radiation.

Non-Ionizing Radiation
Radiation that doesn't have the amount of energy needed to ionize an atom with which it interacts, is called "non-ionizing radiation". Examples of non-ionizing radiation are radar waves, microwaves and visible light.

Ionizing Radiation
Radiation that does have the energy to ionize an atom with which it interacts, is called “ionizing radiation”.

Ohio Safety Congress 2010
Rad Training
Sources of Radiation

There are two main sources of ionizing radiation:
- Natural Background
- Man Made Sources

Radiation Terminology

- Roentgen
- REM
- Rad
- Sub Units
  - Milli
  - Micro

Conversion of rem and millirem

1 rem = 1000 millirem (mrem)
1 millirem = 1000 microrem
5000 millirem = _______ rem?

Personnel Exposure Limits

- ALARA - As Low As Reasonably Achievable

Dose Limits

<table>
<thead>
<tr>
<th>Source</th>
<th>Average Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Body</td>
<td>5 rem/yr.</td>
</tr>
<tr>
<td>Extremities</td>
<td>50 rem/yr.</td>
</tr>
<tr>
<td>Skin &amp; organs</td>
<td>50 rem/yr.</td>
</tr>
<tr>
<td>Lens of the eye</td>
<td>15 rem/yr.</td>
</tr>
<tr>
<td>Pregnant Woman</td>
<td>0.5 rem/term</td>
</tr>
<tr>
<td>Visitors and Public</td>
<td>0.1 rem/yr.</td>
</tr>
<tr>
<td>Cosmic</td>
<td>28 mrem/yr</td>
</tr>
<tr>
<td>Terrestrial</td>
<td>28 mrem/yr</td>
</tr>
<tr>
<td>Radon</td>
<td>200 mrem/yr</td>
</tr>
<tr>
<td>Internal</td>
<td>39 mrem/yr</td>
</tr>
</tbody>
</table>

Natural Background Radiation

Sources: Average Dose
- Cosmic - from the sun and outer space: 28 mrem/yr
- Terrestrial - from the earth's crust: 28 mrem/yr
- Radon - from the soil, (decay of uranium): 200 mrem/yr
- Internal - from sources in the body: 39 mrem/yr
**Man-made Radiation Sources**

<table>
<thead>
<tr>
<th>Sources</th>
<th>Average Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical radiation</td>
<td>54 mrem/yr</td>
</tr>
<tr>
<td>Consumer products</td>
<td>10 mrem/yr</td>
</tr>
<tr>
<td>Industrial uses</td>
<td>&lt; 3 mrem/yr</td>
</tr>
<tr>
<td>Atmospheric testing of nuclear weapons</td>
<td>&lt; 1 mrem/yr</td>
</tr>
</tbody>
</table>

**Average Annual Exposure**

The total from all sources, natural and man made is approximately 360 mrem/yr.

- **Internal** 11%
- **Man-Made** 19%
- **Cosmic** 8%
- **Terrestrial** 8%
- **Radon** 54%

**Radiation Fundamentals**

- **Caution:** Contamination Area

**The Atom**

- Proton
- Neutron
- Nucleus
- Electron

**Charge of the Atom**

The number of electrons and protons determines the overall electrical charge of the atom.

- **Ion** (+1 Charge)
- **Neutral**
- **Ion** (-1 Charge)

**Ionization**

Ionization is the process of removing electrons from a neutral atom.

- **Ejected electron (negative ion)**
- **Remaining atom (positive ion)**

The positively charged atom and the negatively charged electron are called an ion pair.
Ionizing Radiation

Ionizing radiation is radiation which carries enough energy to cause ionization in the atoms with which it interacts.

\[ \alpha \quad (\text{Alpha Particle}) \]

\[ \beta \quad (\text{Beta Particle}) \]

\[ \gamma \quad 1 \text{~m} \quad (\text{Gamma Ray}) \]

\[ \text{n} \quad (\text{Neutron Particle}) \]

Four Types of Ionizing Radiation

The four basic types of ionizing radiation of concern in the nuclear industry are:

- **Alpha Particles**
  - **Characteristics:**
    - Very massive, composed of two protons, two neutrons and no electrons. (Positive charge of plus two)
    - Penetrating Power - Very low. Average range in air is about one to two inches.
    - Shielding - Alpha particles are stopped by a sheet of paper, or the dead layer (outer layer) of skin.
    - Biological hazard - Alpha particles are considered an internal radiation hazard.

- **Beta Particles**
  - **Characteristics:**
    - Very small, negatively charged particle.
    - Penetrating Power - Low. Range in air of several feet and a range of a few millimeters in tissue.
    - Shielding - Most beta particles are stopped by plastic, glass, metal foil, or safety glasses.
    - Biological hazard - Internal, skin and eye.

- **Gamma Rays**
  - **Characteristics:**
    - Gamma (\(\gamma\)) radiation has no charge and no mass. Consists of electromagnetic waves or photons.
    - Penetrating Power - High. Very long range.
    - Shielding - Shielded by very dense materials, such as lead, concrete or steel.
    - Biological hazard - External or whole body.

Dose Rate

- Dose is the amount of radiation you receive.
- Dose Rate is the rate at which you receive the dose
  - Dose rate = dose/time
  - mrem/hr, rad/hr, R/hr

VERY IMPORTANT
ALARA

• Three Elements of Radiation Protection are:

  Time - The less time you spend in the area of radiation, the less of a radiation dose you will receive.

  Distance - The effects of radiation fall off sharply the further you move away from the radioactive source.

  Shielding - Protective material placed between you and the source, like the shielding, also reduces the amount of radiation to which you will be exposed.

Inverse Square Law

Radiation intensity falls off very rapidly as the distance from the point source increases.

Example: If you double the distance from the source of radiation you decrease the intensity of the radiation by a factor of four.

<table>
<thead>
<tr>
<th>Distance (ft)</th>
<th>Exposure (250 mR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62.5</td>
</tr>
<tr>
<td>2</td>
<td>27.7</td>
</tr>
<tr>
<td>3</td>
<td>15.6</td>
</tr>
<tr>
<td>4</td>
<td>10.0</td>
</tr>
<tr>
<td>5</td>
<td>6.9</td>
</tr>
</tbody>
</table>

Radioactive Decay

Radioactive decay is the process of radioactive atoms releasing radiation over a period of time becoming stable (non-radioactive). (Also known as dis-integration.)

Decay chain

Radioactive Material

Radioactive material is any material containing unstable radioactive atoms that emit radiation.

Half Life

Radioactive half-life is the time it takes for one half of the radioactive atoms present in a radioactive sample to decay.

- After seven half-lives the activity of a radioactive sample will be less than 1% of the original activity.
- Radioactive half-life of Cs-17 is 30 years.
- Radioactive half-life of Co-60 is 5.26 years.
Radioactive Contamination
Radioactive contamination is radioactive material in an unwanted place.
- Radiation is a type of energy and contamination is a material.
- It is important to note that exposure to radiation does not result in contamination of the worker.

Types of Contamination
- Removable contamination - contamination that can readily be removed from surfaces and could be inhaled or ingested.
- Fixed contamination - contamination that cannot be readily removed from surfaces.
- Airborne contamination - contamination suspended in air. (breathable air zone)

Possible Effects of Radiation on Cells
- Cells are not damaged
- Cells repair the damage and operate normally
- Cells are damaged and operate abnormally
- Cells die as a result of the damage

Effects of Radiation on Cells
- Radiation causes damage to cells by ionizing the atoms in the cells.
- Ionizing radiation may cause damage directly to the nucleus or any other part of the cell.
- The interaction may cause physical damage, chemical damage, or both to occur to the cell.

Cell Sensitivity
- Radiation damage to cells depends on how sensitive the cells are to radiation.
- Cells that are actively dividing are more sensitive to environmental factors such as ionizing radiation.
  - Examples: blood forming cells, intestinal lining, hair follicles, embryo/fetus.
- Cells which divide at a less rapid pace or are more specialized are not as sensitive to damage by ionizing radiation.
  - Examples: brain cells or muscle cells

Acute Doses
Acute doses are large doses of radiation received in a short period of time.
The body can't repair or replace cells fast enough from an acute dose and physical effects such as reduced blood count and hair loss may occur.
Death can occur if the exposure is high enough.
Chronic Radiation Dose

Chronic radiation dose is typically a small amount of radiation received over a long period of time. Typical examples of a chronic dose are:
- The dose we receive from natural background.
- The dose we receive from occupational exposure.

Chronic vs. Acute Doses

The body is better equipped to tolerate a chronic dose than an acute dose.
- With chronic doses the body has time to repair damage.
- With chronic doses the body also has time to replace dead cells.
- Even sophisticated analysis of the blood does not reveal any biological effects from chronic doses.
- Acute doses may overwhelm the cells repair mechanisms.

Factors Affecting Biological Damage

- Total dose
- Dose rate (how fast)
- Type of radiation
- Area of the body exposed
- Cell sensitivity
- Individual sensitivity

Prenatal Radiation Exposure

Embryo / fetal cells are rapidly dividing which makes them sensitive to any environmental factors such as ionizing radiation.

The Skunk Story

Skunknium-238
Half Life = 7 days
Emits Alpha, Beta, and Gamma

Questions